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Status and prospects of CJPL and the CDEX experiment

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Abstract

The China Dark Matter Experiment (CDEX) pursues the direct detection of light WIMPs towards the goal of a ton-scale germanium detector array at the China Jinping Underground Laboratory (CJPL) located in Sichuan, China. This facility having about 2400 m of rock overburden is the deepest operational underground laboratory in the world. Results on light WIMPs from the CDEX-0 and CDEX-1 employed a germanium detector array with a total mass of 20 g and a crystal mass of 994 g *p*PCGe detector respectively were reported. We highlight the status and perspectives of the dark matter programs at CJPL, in particular the project of CDEX-10.

Selection and peer review is the responsibility of the Conference lead organizers, Frank Avignone, University of South Carolina, and Wick Haxton, University of California, Berkeley, and Lawrence Berkeley Laboratory

Keywords:
Dark matter, Radiation Detector, Background radiation

1. Physics Motivations and Goals

The nature and identity of the dark matter of the Universe is one of the most challenging problems facing Astronomy, Cosmology as well as particle physics [1]. The Weakly Interacting Massive Particles (WIMPs, denoted as χ) is one of well-motivated candidates of dark matter. Current dark matter searches experiments aim for direct detection via elastic scattering off nucleon in terrestrial detectors. The anomalous excess of events at low energy with DAMA [2], CoGeNT [3], CRESST-II [4] and CDMS-II(Si) [5] data subsequently attributed to a possible light WIMP signature in conflict with null results from other experiments [6, 7, 8, 9]. The theme of the CDEX research program is on the light WIMP searches. Ultra-low energy threshold germanium detectors were identified [10] as effective means to probe the light WIMPs and motivated by the development of point-contact germanium detectors [11].

2. Experimental Set-up

The facility CJPL was inaugurated at the end of 2010. It is located at southwest Sichuan, China, reachable from the provincial international airport at Chengdu via a 50 min flight to Xichang followed by 2 hour drive on a private two-lane motorway. The laboratory is owned by the YaLong River Hydropower Development Company, and

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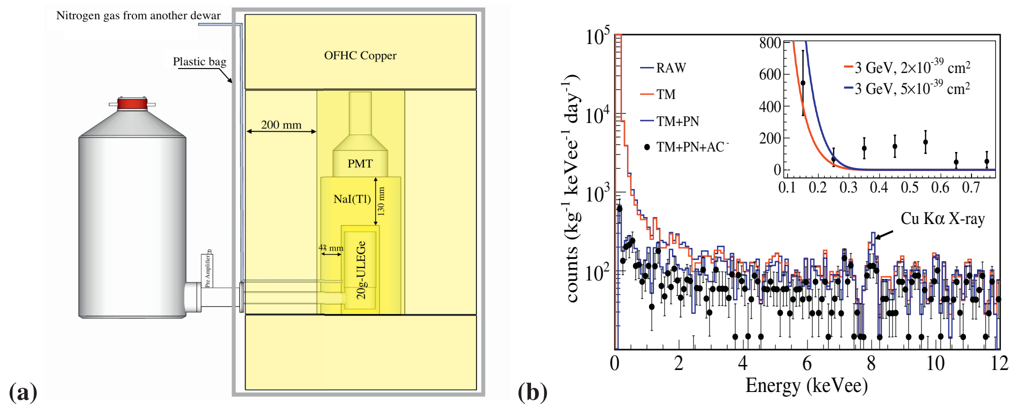

Figure 1. (a) Schematic diagram of the experimental set-up for 20 g germanium detector array which surrounded by a NaI(Tl) anti-Compton detector, as well as the enclosing OFHC Copper shielding. The entire structure is placed inside a passive shielding system described in Ref. [13]. (b) Measured energy spectra of 20 g germanium detector array, illustrating the raw spectra and various cuts step by step. The low energy spectra after subtraction of a flat background defined at high-energy γ-rays, superimposed with the predicted spectra for 3 GeV WIMPs with $\sigma^{SI}_{\chi N} = 2 \times 10^{-39}$ cm^2 and $\sigma^{SI}_{\chi N} = 5 \times 10^{-39}$ cm^2.

managed by Tsinghua University, China. With a rock overburden is about 2400 m giving rise to and a measured muon flux of 61.7 yr^{-1}m^{-2} [12], CJPL provides an promising location for low-background experiments. In addition, A polyethylene (PE) shielding structure with thickness 1 m and dimension 8 m × 4.5 m × 4 m (Height) has been constructed for the CDEX program at CJPL. Prototype detectors can be installed with the shielding materials from outside in lead, boron-doped polyethylene and OFHC copper inside this PE-housing [13, 14].

3. Results of CDEX-0 and CDEX-1 experiments

Based on a pilot measurement with an existing prototype germanium detector with sub-keVee ("ee" denotes electron equivalent energy) sensitivities at 20 gram modular mass [15], final results of the CDEX-0 experiment at CJPL has been reported [16]. The physics threshold of 172 eVee at 50% signal efficiency was achieved with 0.784 kg-days of data. The schematic design is described in Figure. 1a. NaI(Tl) crystal scintillator serves as anti-Compton detector which enclosed the cryostat. The analysis details has been described in Ref. [16]. Measured spectra from raw spectra to those at the different stages of the analysis is shown in Figure 1b. Copper X-ray induced by ambient background was observed due to the thin layer surface of n$^+$ electrode. The residue background after subtracting the flat background above 1.5 keVee is depicted in the inset of Figure 1b.

P-type Point-Contact germanium detectors [11](*p*PCGe) offer sub-keVee sensitivities with detector of kg-size modular mass to probe the low-mass WIMPs, an improvement over the conventional ULEGe design. Intensive R&D efforts [6, 17] are pursued to optimize the application of Point-Contact germanium detector in dark matter searches. An exposure of 14.6 kg-day with a 994 g p-type point-contact germanium detector at CJPL has been studied the sub-keV background including eight L-shell peaks predicted by those K-shell peaks and flat spectrum from ambient γ-source. The analysis methods were adopted by (1) the time interval before/after the reset-inhibit signals from preamplifier (TT cut); (2) the pedestals of shaped amplifiers (Ped cut); (3) the basic pulse shape discrimination (PSD cut) [18]. The measured spectra with various cuts and their efficiency corrections are shown in Figure 2a. After subtraction of known background, the spectra has placed sensitivities on spin independent cross section in the Figure 2.

Latest results from CDEX-1 experiment with a *p*PCGe were recently reported [19]. The earlier measurement were operated in the absence of Anti- Compton detector and prior to surface event suppression. The new result with these two crucial features incorporated. All events above the analysis threshold of 475 eVee can be quantitatively accounted for with the understood background channels. An order of magnitude improvement over our previous results is achieved. In particular, the CoGeNT-2013 allowed region[3] is excluded with an identical detector technique provided direct comparisons without the uncertainties due to model dependence introduced via the choice of astrophysical and nuclear parameters.

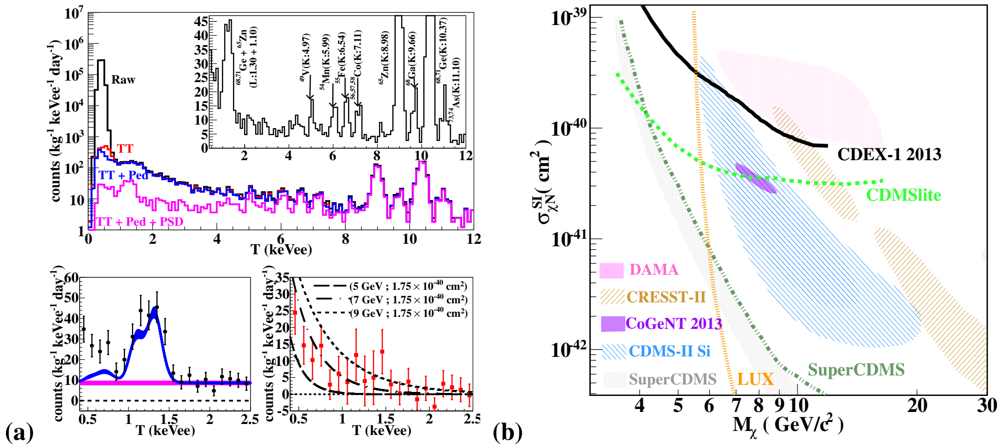

Figure 2. (a) The observed energy spectra showing raw data and those stages of selection cuts of TT, TT + Ped and TT + Ped + PSD cuts are given in upper plot. Background after corrections of various efficiencies as well as fiducial mass is shown in the inset plot. Eight *K*-shell peaks for *L*-shell peaks prediction are identified. Measured spectra Ranged of 0.4 - 2.4 keVee was shown in the left bottom together with the calculated *L*-shell background contribution and the flat γ background with the expanded statistical error band. The residual spectrum was shown in the right bottom, superimposed with the predicted spectra for WIMP mass of 5 GeV, 7 GeV, and 9 GeV with spin-independent cross-section $\sigma_{\chi N} = 1.75 \times 10^{-40}$ cm^2. (b) The 90% confidence level upper limit of spin-independent χN coupling derived from this data, superimposed with the results from other benchmark experiments [2, 4, 3, 5, 9, 18, 7, 8].

4. Status and Plans

The CDEX pursues direct searches of light WIMPs towards the goal of a ton-scale germanium detector array at the CJPL. The first phase of CDEX experiment(CDEX-1) has implied two crucial features including the NaI(Tl) crystal scintillator as anti-Compton detector and differentiation the bulk events from surface ones. Intensive studies on the background at sub-keVee regime and selection pressures of bulk and surface events at near noise edge. Design and construction of PCGe array to the 10-kg total mass range is ongoing, shown in Figure 3. This new detector will be shielded and enclosed in a ton-scale liquid argon chamber which serves as both cryogenic medium and active shielding and anti-Compton detector where the scintillation light will be read out by photomultipliers.

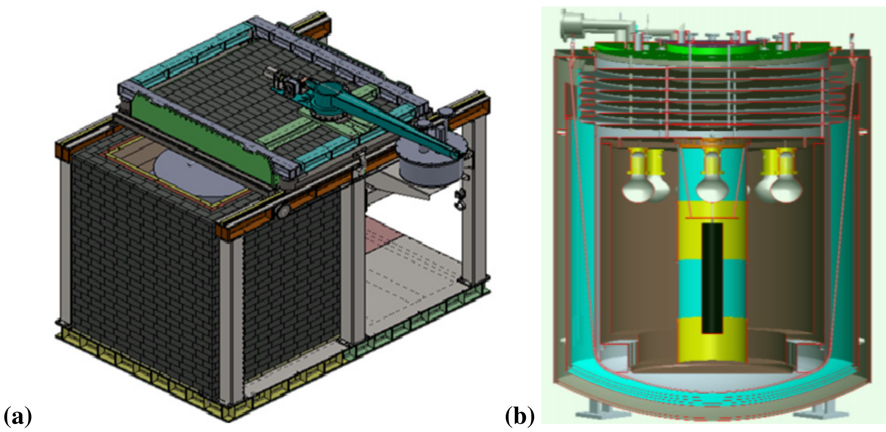

Figure 3. Drawings of (a) the mechanical supports and (b) layout of detectors and Liquid argon dewar of CDEX-10.

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